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Single-Layer Amorphous Carbon Anti-Reflective Coatings Obtained by The Pulsed Laser Deposition Method

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Abstract: Single-layer a-C anti-reflective coatings on the Si and GaAs substrates were obtained by using of a Q-switched nanosecond pulsed laser deposition method. It is established that single-layer a-C coatings effectively reduce the high reflection of substrates (on average to 5 % for Si and 8 % for GaAs in 400-750 nm wave range). Used by us technology for fabrication of a-C anti-reflective coatings is very simple (excludes high-energy implantation, high-temperature diffusion and deposition processes) and applied for the first time.

Keywords: Pulsed laser deposition , anti-reflective coating, amorphous carbon,, photosensitive structures.

1. Introdction

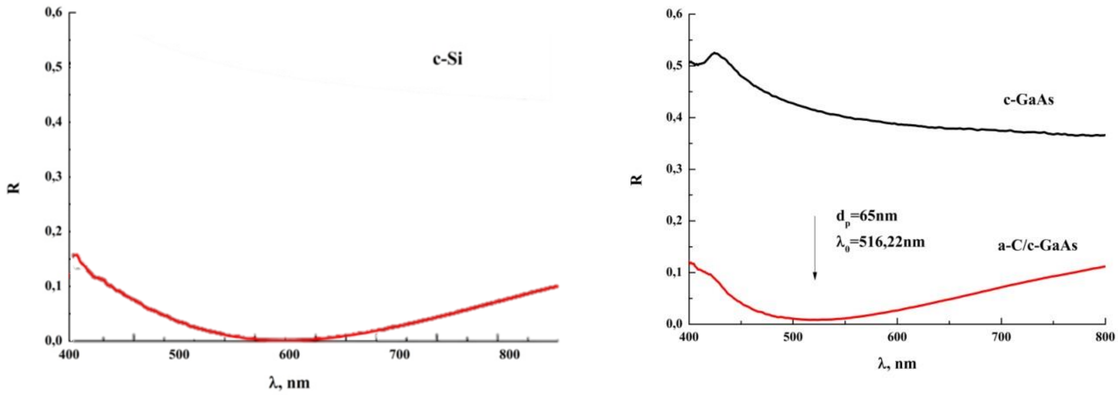
It's obvious that suppression of visible light reflection from material surfaces is an important for various applications such as photosensitive structures, solar cells, flat-panel displays, etc. Therefore, attention to the design of technologies and novel materials for anti-reflective coatings (ARC) is in demand. As an alternative approach, further investigations in this field led to the use of metasurfaces (two-dimensional structures) as an intermediate layer for visible light ARC. In particular, were developed an ARC design based on a $10nm$ thick layer of silver nanodiscs (effective refractive index less than 1.0), which enabled strong suppression of reflection from the underlying substrate [1]. But we adhere to the opinion that single-layer ARC is more practical in the case of amorphous carbon $(a-C)$ film, since it consists of only one element, which has an ability of broaden variation of refractive index and band-gap depending on technological conditions of fabrication. We continued the investigation of application possibilities of $a-C$ film as a visible light single-layer ARC. The pulsed laser deposition (PLD) technique was chosen as a fabrication technology, since ta-C films with high (up to 85%) sp^3 bonds were obtained earlier by using of this technology [2-4]. Si and $GaAs$ were used as a substrate.

Up to date have not been reported about application of PLD for fabrication of visible light ARC based on a-C film. Primarily it caused by low band-gap of PLD-produced $a-C$ films. At second, there are not comprehensive and trusted experimental studies of the refractive index and sp^3/sp^2 hybridization ratio of C for nano-sized $(\leq 100nm)$ films. And, at third, PLD is not recognized as an industry technology. Although practically all materials needed for functional electronics are obtained by this technology, the wide application of this method in production of electronic components is limited due to the difficulty of obtaining films with required qualities on relatively large areas. There are a few successful applications of PLD from which promising are broad band $(1-6\mu m)$ infrared detector based on $(p)InSb-(n)CdTe$ lattice matched heterojunction [5] and an α -particle sensitive $a-C/n-Si$ heterostructure [6]. PLD is still an alternative technology as yet.

2. Experimental part and results

$a-C$ films were deposited onto factory quality polished Si and $GaAs$ substrates $(400nm$ thickness) at room temperature by ablation of graphite target in the vacuum. The deposition unit consists of a Q-switched YAG: $Nd3+$ laser $(1.064\mu m$ wavelength, $30ns$ pulse duration, laser energy - $0.35J$ per pulse, repetition rate - $1Hz$) and a vacuum chamber with residual gas pressure $2\cdot 10^{-5} tor$. AR properties of fabricated coating were studied from reflectance spectra on thin-film measurement system Filmetrics F20 at the normal incident of light. Thicknesses of film $(0.28nm$ per pulse) were determined on profiler Mitutoyo Surftest SJ-410.

Based on the studies of optical reflection spectra, it is established that single-layer a-C coatings effectively reduce the high reflection of substrates (on average to 5% for Si and 8% for $GaAs$ in $400nm-750nm$ wave range. The reflection minimum (0.086%) on the Si substrate is observed at a wavelength $\lambda_0 = 575nm$ (fig. 1a; $a-C$ film thickness - $71nm$). This value is 0.84% at a wavelength $\lambda_0 = 516.22nm$ for a $GaAs$ substrate coated with the $65nm$ thickness of $a-C$ film (fig. 1b).



a) b)

Fig. 1. a-C ARC on a) Si and b) GaAs.

Used by us PLD technology for fabrication of $a-C$ anti-reflective coatings is very simple (excludes high-energy implantation, high-temperature diffusion and deposition processes) and applied for the first time.

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